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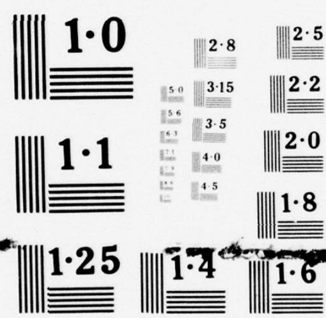

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DEFENSE SYSTEMS MANAGEMENT SCHOOL

STUDY TITLE: DECISION ANALYSIS FOR THE PROGRAM MANAGER

STUDY GOALS: To evaluate and propose decision analysis methods and techniques for use by a Program Manager during all phases of system development.

STUDY REPORT ABSTRACT

Decision analysis techniques applicable to program management are examined and related to some of the critical decisions a Program Manager must make during the acquisition life cycle of major weapons systems. It is shown in detail how these techniques can be applied throughout the development cycle to assist the Program Manager in developing a systematic approach for analyzing and determining critical factors and their interrelationship and impact upon a particular course of action. Using this approach it is demonstrated how decision analysis techniques are most important to a Program Manager particularly when he is faced with very intricate and complex problems of major weapons system acquisition.

KEYWORDS: MATERIEL ACQUISITION PROGRAM MANAGEMENT DECISION MAKING C/SCSC PROJECT MANAGEMENT LIFE CYCLE MANAGEMENT COST ANALYSIS

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Charles R. Lindsey, Ltc. USA	PMC 74-1	May 1974

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DEFENSE SYSTEMS MANAGEMENT SCHOOL

PROGRAM MANAGEMENT COURSE
INDIVIDUAL STUDY PROGRAM

DECISION ANALYSIS
FOR THE PROGRAM MANAGER

STUDY REPORT
PMC 74-1

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DECISION ANALYSIS

FOR THE PROGRAM MANAGER

An Executive Summary
of a
Study Report
by

Charles R. Lindsey
LTC. USA

May 1974

Defense Systems Management School
Program Management Course
Class 74-1
Fort Belvoir, Virginia 22060

EXECUTIVE SUMMARY

The role of a decision maker is a difficult job and in the case of a Program Manager (PM) his task of decision making may be even more difficult because of the complexity and interdependency of factors related to typical problems he must resolve. This study examines some decision analysis techniques that are applicable to program management and recommends an approach for use by a PM to aid in his decision making.

The approach recommended is a modified version of a process that the Army calls estimate of the situation. Using the estimate of the situation as a guide, a somewhat different format for the process is recommended. The new format is called Estimate of the Circumstances. Other procedures, such as requiring each staff section chief to prepare an estimate for his point of view, remained the same. Content of the estimate was changed to reflect information required and applicable for program management.

A system for collecting, analyzing and evaluating information required as input to the estimation report is also proposed. The system contains a Program Management Information System (PMIS), a network-time oriented system and analytical techniques which in some cases may provide adequate information for decision making. However, for complex problems

all elements of the system are used to produce an adequate analysis and evaluation.

A comparison of this system is made with the system used to design communications systems such as radios, radars and computers. Results of the comparison show that the systems are identical and that in view of accuracies achieved, particularly with computers, similar accuracies in estimating and predicting results of problems faced by a PM could be achieved. Although these procedures can produce excellent results, it is noted that they do not in themselves provide the solution but a solution. The PM must still decide if the solution derived through the use of these techniques is acceptable.

It is concluded that in spite of the shortcomings of the proposed system, excellent approximations can be achieved and that the estimate of the circumstances procedure does provide the PM with a capability for making sound and logical decisions.

DECISION ANALYSIS

FOR THE PROGRAM MANAGER

STUDY REPORT

Presented to the Faculty

of the

Defense Systems Management School

in Partial Requirement of the

Program Management Course

Class 74-1

by

Charles R. Lindsey
LTC. USA

May 1974

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DECISION ANALYSIS
FOR THE PROGRAM MANAGER

Introduction

During the life cycle of major weapons system acquisition a Program Manager (PM) must make numerous decisions that often involve selecting an optimum or best course of action for accomplishing various tasks. Many of these decisions involve complex and interrelated factors that require detailed analysis and evaluation. Complicated problems of this nature demand a comprehensive and thorough decision process if sound and logical decisions are to be made. Although there are many decision analysis procedures or systems none of them are completely capable of incorporating the many varied and intangible factors a PM must consider. This report examines some of the methods that can be utilized and proposes a system that could assist the PM in making decisions.

The proposed system involves the use of a Program Management Information System (PMIS), a network system, analytical techniques and what is called decision tree analysis. It is demonstrated how some of these techniques in themselves provide adequate information for decision making for those problems that are relatively simple. For the complicated problems it is shown how all of these techniques are used in conjunction with each other to provide information that is combined and evaluated using a proposed format called an estimate of circumstances.

In chapter two decision analysis techniques are discussed in general to include the strong points and pitfalls that one must recognize when using these techniques. Also discussed is the business management orientation of current decision analysis techniques and the lack of any significant amount of literature on applications for project management. Some of the methods applicable to project management is examined in chapter three. An explanation of each method is given along with how they are to be used in the system proposed.

Chapter four discusses analytical techniques applicable for analyzing and evaluating such critical factors as cost, schedule and technical performance. It is shown how to estimate, evaluate, and analyze these factors and determine criticality of their relationship to the problem to be resolved. Chapter five discusses psychological, social, cultural and organizational factors that must be considered when making a decision. Since these factors are not easily evaluated using analytical methods, a subjective means for handling these factors is proposed.

The estimate of circumstances format is discussed in chapter six. It is shown how through the use of this format all data provided from analysis techniques previously described is combined, analyzed, and evaluated. It is this evaluation process that provides the PM with adequate information to make a decision.

Some typical critical problems or decisions a PM must make during all phases of life cycle development are examined in chapter seven and it is shown how previously discussed analysis techniques can be used to assist the PM.

Chapter eight contains the summary and conclusions and it is concluded that decision analysis techniques are effective means for assisting the PM in making decisions.

DECISION ANALYSIS PROCESSES

Decision analysis techniques are defined as any process that provides a logical and orderly means for defining a problem; determining all critical factors that have impact on the problem; selecting feasible solutions; analyzing and evaluating alternatives and providing a possible solution. It is appropriate to emphasize that decision analysis techniques do not provide the solution but a solution to a problem. The decision maker still must decide if the solution derived from the analysis is optimum for resolving his problem. In other words, the results of an analysis technique is accurate to the extent of the accuracy of quanitative data, facts and assumptions used in the analysis. Even if all data and etc., used is accurate, validity of the results could be questioned because results are only approximations of what could or may happen given certain circumstances. However, regardless of the approximate nature of results, decision analysis, if conducted properly, provides a decision maker with considerable knowledge and insight as to inter-relationships of critical factors pertaining to a problem and with such knowledge the making of a sound and logical decision is greatly enhanced.

Most of todays literature on decision analysis is oriented toward business management or the engineering sciences where problems are generally structured. Such structured problems

are readily adaptable to decision analysis techniques. Consequently, very good approximations are obtained. The PM's problems are generally unstructured and although some of the literature address unstructured problems and, in some cases, discuss the similar problems of PMs, there isn't enough data available that a PM could review to learn analysis techniques.

The unstructured nature of a PM's problems stem from many intangible and difficult, if not unpredictable, factors such as life cycle cost, resolution of a technical problem before it delays entire projects and will a modification or engineering change proposal (ECP) provide the required performance. These factors are difficult to quantify but must be, if analysis techniques are to be applied for resolution of typical problems faced by a PM.

Most analysis techniques, as mentioned previously, are designed for structured problems and the few that are adaptable to unstructured problems may require some minor adjustments before they can be applied to most problems of a PM. In the next chapter some techniques that are adaptable will be discussed and it will be shown that although the techniques may not be perfect for a PM's problems, with due considerations for the unstructured nature of the problem, an adequate approximation can be obtained.

MANAGEMENT TECHNIQUES

Project management is a difficult task, and traditional organizational structure and management techniques have proved awkward or ineffectual in accomplishing it. The PM is responsible for getting the job done on schedule within allowable cost. However, he must often accomplish his goal by employing the efforts of many separate organizations and individuals, most of which are not under his direct control. The techniques discussed in this chapter provide the basic tools needed by a PM in planning , scheduling and controlling the work under these conditions.

The PM's primary task is to direct and coordinate toward one goal the work of several groups involved in the project; yet, the complexity of todays operations forces him to divorce himself from details, to deal only with the broad aspects of the problem. He is inclined to think and act in generalities because he lacks the techniques or management aids which would enable him to comprehend the whole operation in detail. He does not always know which activities are critical and require special attention, or what effect a delay or failure in one activity will have on others following it or on the success of the project as a whole. What is needed is a system which will provide the PM with an up-to-date picture of the operation at all times, and which would follow a uniform system understood

by all. The methods of this chapter are designed to fill these needs.

The first and probably the most impoprtant component of the proposed decision analysis system is the Project Management Information System (PMIS). A PMIS in its broadest sense is defined as a set of policies, models, procedures and files of information which operate to record, manipulate, store, retrieve, process and display information useful in planning, scheduling, executing and controlling complex projects, which cut across organizational and functional lines and which must achieve the specified results at a particular point in time and within a given cost budget. (1)[1]

A PM's most critical problems all relate to cost, schedule, and technical performance in some manner. Therefore, the primary objectives of a PMIS should be to obtain, analyze and evaluate data of this nature. To develop such a system the Work Breakdown Structure (WBS) should be used as the basis for establishing a reporting system under the Cost/Schedule Control Systems Criteria (C/SCSC) established by the Department of Defense (DOD).

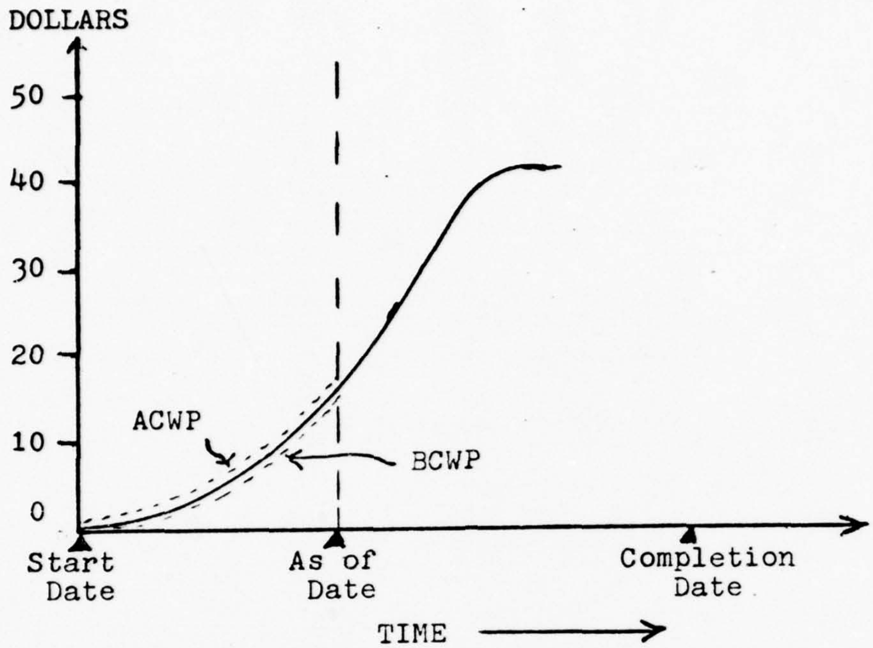
With C/SCSC the PM has an effective means for keeping track of overall contractor progress. The basic unit for tracking contractor performance is the monthly Cost Performance

[1] This notation will be used throughout this Study Report for sources of quotations and major references. The number in parenthesis is the source listed in the Bibliography.

Report (CPR). From the CPR the PM is provided data on work package completion and scheduled; funds expended and projected expenditure; material committment and expenditure and variance analysis of cost and schedule. With this data a Performance Analysis Curve can be constructed using (1) Budgeted Costs for Work Scheduled (BCWS); (2) Budgeted Cost for Work Performed (BCWP); and (3) Actual Costs for Work Performed (ACWP). With these three factors then cost and schedule variances can be established. The cost variance is the difference between the BCWP and the ACWP. At any point in time it shows whether the work actually performed has cost more or less than budgeted. The schedule variance is the difference between BCWS and BCWP. At any point in time it shows, in dollars, the difference between work scheduled to be accomplished versus work that was actually accomplished.

Figure 1 shows two examples of the Performance Analysis Curve. Figure 1a shows that the program is on cost and schedule. Although this situation could happen, it is somewhat unrealistic and should be investigated. Figure 1b shows that the program is behind schedule and over-run in cost. This situation indicates technical difficulties.

C/SCSC provides the PM adequate information on contractor performance but nothing about other factors such as various supporting agencies, commands and environmental factors that may affect the program. When dealing with supporting agencies



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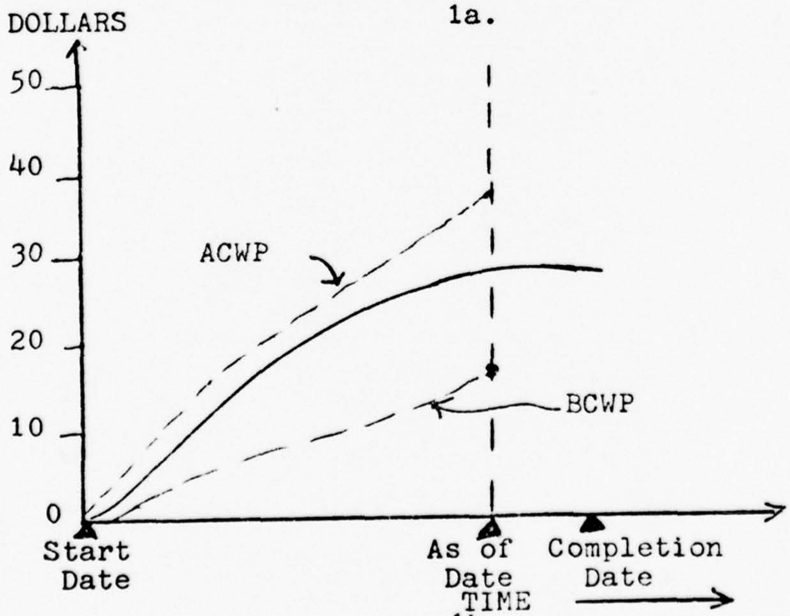

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Figure 1. Performance Analysis Curves.

C/SCSC types of reports should be used wherever applicable and practical. It is recognized that supporting agencies in all services are not organized and validated under C/SCSC. However, the Army has started to organize some of its arsenals under this concept and it is anticipated that in the near future all services supporting activities will be validated under C/SCSC. Until this is accomplished the PM should, through memorandums of agreements, negotiate between himself and the supporting command reporting procedures similar to the CPR.

For environmental factors, a system of liaison, periodic visits and simply keeping attuned to what is happening outside of the PM's organization should be established. This area will be discussed in Chapter five.

The PMIS envisioned gives the PM a means for relating cost, schedule and progress toward developing a weapons system. Using this system, particular areas of difficulty can be identified; but how the problem relates to the overall project cannot be ascertained. To provide this visibility a network system based on time is essential. A network time oriented system is defined as an operations-related system that tells the manager when and how (in terms of sequence of operations) the program will be accomplished. (1)

The development of a network system consists of three phases. The phases are (1) planning; (2) scheduling; and (3) monitor and control. The planning phase consist of breaking

down the project into discrete activities and events and arranging these in logical sequence in the network.

The schedule phase consists of estimating the duration of each activity and then totaling these times, proceeding logically through the network, to determine overall duration of the project. If this procedure is reversed, starting at the end event and subtracting the activity durations, you can derive useful schedule information including identifying the critical path, the longest path of activities, through the network. Its length determines the project duration, and all activities not on this path may have delay time called slack.

In the monitor and control phase, as actual completion of each activity is reported, changes are made and a new analysis determines impact of progress and changes on the future plan and schedule. The network plan must be periodically updated and analyzed if it is to be a viable management measure. (1)

Figure 2 shows a simple network system (plan). Note that activity A must be completed before activities B or C can be started. Also note that activities R, S, and T must be completed before activity W can begin. The critical path is shown by the double line. Numbers between events represent estimated times required to complete an activity before proceeding to the next phase.

The WBS provides an excellent means for breaking the project down into discrete elements and should be used in conjunction

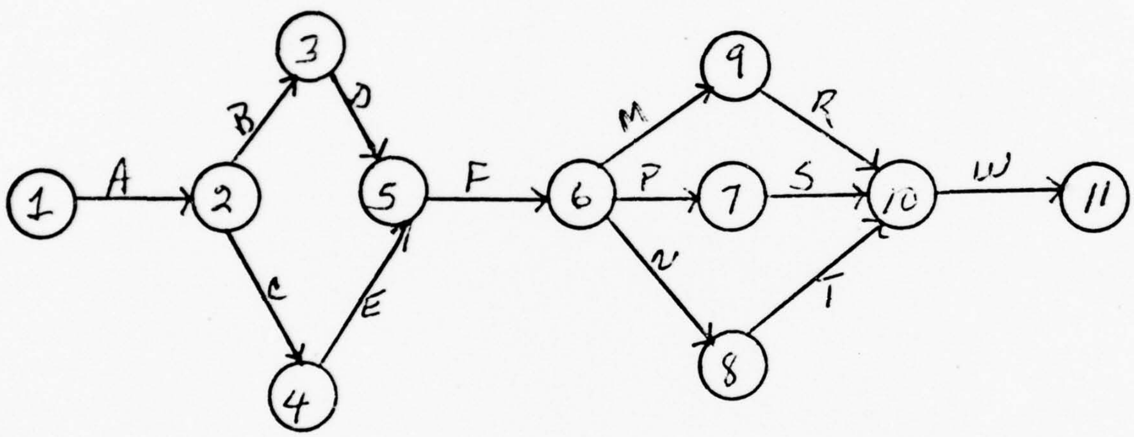

Figure 2. A Network System.

with the Advanced Development and Program Management Plans to develop the network plan. Successful integration of all activities of these plans into the Network system provides the PM a valuable tool for determining the impact of a particular action on the overall program.

Once all pertinent information and the inter-relationships have been determined using the PMIS and the Network System some problems can be evaluated with analytical techniques. The basic techniques required in the proposed decision analysis system are discussed in a general manner in this chapter. A more detailed explanation is covered in chapter four.

Three techniques are used. They are sampling, estimation, and prediction. All three involve the use of subjective judgments to some extent. For example, a PM is constantly faced with problems of estimating costs, schedules and technical performance. The techniques used in estimating will not eliminate the uncertainity but will give the PM enough data which indicates whether his estimate is reasonable. Using this estimate the PM can then predict if certain actions can be completed on schedule or whether a certain technical parameter can be obtained. As mentioned earlier, these methods cannot and should not be expected to provide the solution but a reasonable approximation of what may happen under given circumstances is obtained.

These techniques are used for the relatively simple problems that do not involve complex relationships. For these types of problems decision tree analysis should be applied.

A decision tree is a network of branches corresponding to possible alternatives with subsequent sequences of acts and events, stemming from an origin at the left to a time horizon at the right. Acts (represented by squares) are choices that one controls or can make. Events (represented by circles) are possible outcomes determined by chance. A path through the tree represents a possible sequence of acts and events characterized by a value at the right of the diagram. This value may represent a loss or a gain. (3)

Figure 3 shows a completed decision tree for a hypothetical problem. As PM, you must decide whether or not to accept a controversial and critical engineering change proposal (ECP) submitted by a contractor during the latter stages of full scale development. After analyzing the problem you know that without the ECP life cycle cost (LCC) may increase (loss of) by \$60,000,000. Also you know that there is a fifty-fifty chance that the ECP will be successful. If you decide to reject the ECP, the program is cancelled and a loss of \$60,000,000 is incurred. If you accept the ECP and if it works your loss is then \$20,000,000. You are then faced with the problem of deciding whether to stop production and redesign for a total loss of \$40,000,000 or to continue and try to retrofit models at a later date with the ECP for a loss of \$10,000,000. Evaluating this tree diagram using expected value and rollback techniques show that the decision has to be made between accepting the ECP with an expected loss of

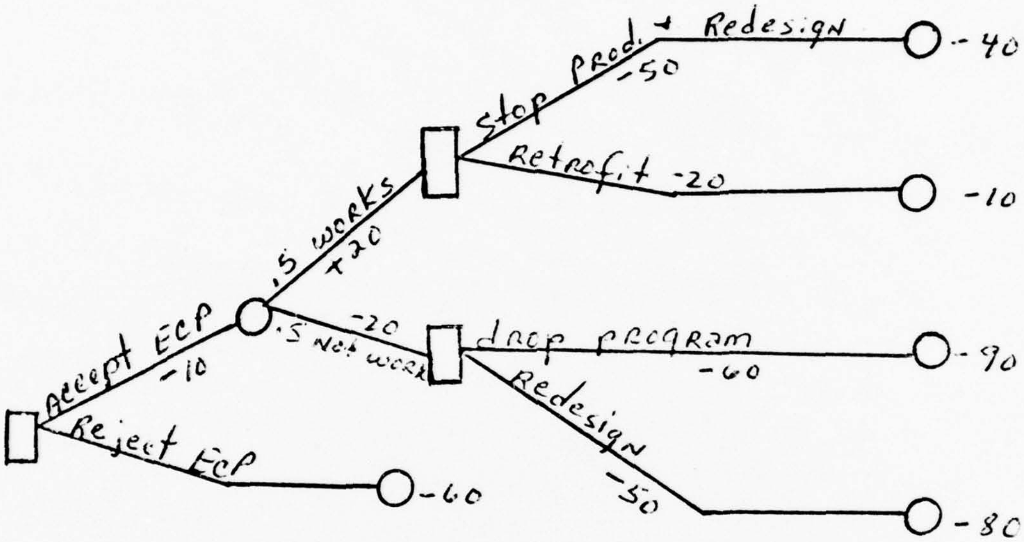

Figure 3. Tree for the ECP Example.

$45,000,000 or rejecting the ECP with a known loss of $60,000,000. A detailed explanation of tree diagram construction, expected values and roll back techniques is contained in references 3 and 4. The intent here is to merely show, without detailed proofs, that a tree diagram can provide the PM a valuable tool for analyzing complex problems.

The probabilities used in the diagram can be known or estimated. A means for estimating these probabilities and establishing values (dollars) for use in the diagram will be covered in the next chapter.

SAMPLING, ESTIMATION AND PREDICTION

Analytical techniques of sampling, estimation and prediction of outcomes are powerful techniques for coping with the many uncertainties associated with project management. Properly applied and evaluated these methods will considerably reduce the degree of uncertainty of many problems.

By reducing uncertainty, it is meant that these methods will provide a PM with a means of determining how probable a particular event will occur or the probability of success of a particular course of action.

The mean and standard deviation are the two most important values from which inferences about a process can be made. In subsequent paragraphs derivations of these values using sampling and estimation will be examined and shown how they can be used to predict outcomes.

The sampling technique involves observing an experiment and recording the outcome values. Assuming that the experiment is conducted a number of times and all outcome values are recorded a sample mean can be determined. The sample mean is defined as $X = \sum_{i=1}^{n} x_i$. In other words record the outcome values and determine the numerical average. From this average the sample variance can be determined. The sample variance is defined as $S^2 = \sum_{i=1}^{n} (x_i - \bar{x})^2/(n-1)$. The standard deviation is the square root of S^2.

With these values one can, through the use of standard formulas, estimate and predict the probability of occurrance of particular events. (By standard formulas reference is made to the binomial, negative binomial, geometric and hypergeometric distribution formulas. For a detailed explanation of these procedures refer to reference 3.) In addition to the standard formulas, the concept of conditional probability and the Bayesian method of estimation can be used. (See reference 4).

If large samples are taken, the mathematical laws of probability guarantees that the sample means approaches the true mean with certainty. In particular, the law of large numbers states that as the sample size increases, the difference between the true mean and the sample mean becomes negligible. However, the laws also show that the sample mean is an unbiased estimate of the true mean and, therefore, the sample variance is a good estimate of the true variance. (4)

In addition to determining the means and variances of estimates one can determine, again from standard formulas, the probability of error in these estimates. Therefore, knowing that an error of 5 percent or 10 percent may exist in an estimated outcome, allowances or compensations could be made to accommodate the deviations.

The last technique considered is that of hypothesis testing. This technique, using the Neyman-Pearson Criteria, is a most powerful test for estimating whether a simple hypothesis is

true. (5) This method is far superior to the Bayes method in that knowing the a priori probability and cost data are not necessary. All that is needed is the distribution function of the two hypotheses and a determination of an appropriate significance level. This method assures that the optium trade off between making a Type I or Type II error is accomplished. (5)

The procedures described thus far can be used to some extent individually or in conjunction with each other to evaluate many problems faced by a PM. For example, is the mean flying time of a missle equal to a certain value; should a lot of ammunition be accepted if a certain number of defective rounds are found by inspection; is the probability of a hit by a missile equal to .8 and many similar problems can be evaluated.

These techniques, if used properly, provide good approximations for a PM's problems. In the engineering sciences and particularly the electronics area, systems are designed using these techniques. For instance, communication systems, to include radios, radars and computers are designed and constructed through the use of methods outlined in this chapter. Experience has shown that these systems and especially computers, have an error rate of approximately 10^{-4}. (6)

These communication systems all follow the same decision process. First, the incoming signal is sampled; second, based on the average value of the sample, which is the same as the sample mean, a decision is made as to what signal was sent. In the case of computers, the decision is between two equally

likely siganls called zero or one. When deciding between two equally likely situations the probable error is .50 percent but the computer makes millions of decisions per minute on signals like these and yet makes approximately 1 error in about 10,000 and sometimes, 100,000 decisions. Thus these analytical techniques are powerful tools and can be used to assist a PM in deciding between alternatives.

ENVIRONMENTAL FACTORS

Environmental factors are intangibles that must be considered when confronted with making a decision. In this paper these intangibles are considered to be political, social, and cultural matters that arise. These factors occur internally in the PM's office and within supporting operating commands and higher headquarters. Recognizing and accommodating all of these factors becomes a difficult if not impossible task. Trade offs or balancing these factors to achieve the optium/best solution is the most one could hope to accomplish. This chapter examines a simple technique that could be used for balancings.

To insure that the PM's office has accurate, and timely information regarding these factors, an effective liason system between all organizations to include the contractors, must be established and maintained. Each staff section of the PM's office must interface with their counterparts of organizations involved and the PM must establish the contact between the heads of the organizations concerned. If pursued diligently this approach enhances receipt of information.

Once all factors have been identified a determination of their relative importance and effect upon a particular course of action must be made. To determine the impact is rather easy but to establish relative importance is difficult if only subjective means are used. Therefore, combining subjective evaluations and techniques described in the last chapter offer the best means of evaluation.

The subjective part of this approach requires each staff section chief and the PM to estimate the value of each factor, with zero being the least important and a value of ten being the most important. The analytical part involves using the sample mean of these estimates as the value of relative importance. Although the estimates are determined subjectively, the overall approach is analytical and is the same method used by the communication systems described in the last chapter to make decisions. Consequently, an accurate assessment of the true value of importance is obtained.

ESTIMATE OF THE CIRCUMSTANCES

In today's environment the complex problems of program management require a logical and orderly examination of all factors affecting the resolution of a problem to reach a sound decision. How a PM arrives at a decision is a matter for his personal determination. However, sound decisions result best from a thorough, clear, unemotional analysis of all pertinent data. Because problems associated with program management are complex, the organization and consideration of data in an orderly sequence make a logical analysis easier and the production of sound conclusions more likely. This orderly sequence is an integral part of what is called the Estimate of the Circumstances formulated as an aid for the PM in applying thoroughness, clarity, judgment and professional knowledge to each situation to reach a sound decision.

In previous chapters management and analytical techniques for obtaining and evaluating information required for decision making were presented. However, these techniques in themselves do not provide the necessary integration of all factors that must be considered. To provide the integration necessary for obtaining as much visibility and evaluation of all factors related to making a sound decision it is proposed that PMs adopt the use of a procedure called the Estimate of the Circumstances. This estimate would be similar to the estimate of the situation procedure now being used by combat commanders

in deciding a course of action. The differences between the two procedures would be in names of the paragraphs, content and the method of analyzing and comparing alternatives.

The estimate of the circumstances has five paragraphs. They are issue, the situation and alternatives, analysis of alternatives, comparison of alternatives and, last, the decision paragraph. This last paragraph would be recommendations in the case of a staff officer's estimate and decision in the case of a PM's estimate. The contents of each paragraph are discussed in succeeding paragraphs.

The issue paragraph contains a clear and concise statement of the problem or in other words what must be decided.

The situation and alternatives paragraph contains the overall situation and feasible alternatives for resolving the issue. There are two purposes for considering the overall situation in paragraph 2 of the estimate: the first is to consider all elements and aspects of the situation that affect the issue so as to facilitate development and analysis of alternatives and the second is to formulate feasible alternatives that will resolve the issue. It is essential to include all facts and assumptions that will affect the issue. These could include facts pertaining to resources available and actual or potential obstacles to success. These facts are analyzed separately as well as in relation to one another. Logical deductions are made as to the effect of each fact on the issue and on the determination of possible alternatives. The facts obtained in paragraph 2 of the estimate are fur-

nished to the PM by his staff. Paragraph 2 of staff estimates would contain facts relative to their respective areas of concern.

The purpose of the third paragraph, analysis of alternatives, of the estimate is to identify the advantages and disadvantages of each alternative, to add refinements and embellishments, to isolate critical factors and incidents that could occur during implementation of a decision and to assist ultimately in determining the best alternative.

The purpose of the fourth paragraph, comparison of alternatives, is to compare the alternatives that will resolve the issue, i.e., those alternatives that are feasible, so that a conclusion as to the best alternative can be reached. In this paragraph the information contained in the preceding paragraphs is analyzed and interpreted into a comprehensive evaluation of each alternative. The facts, assumptions, cost schedule, and technical data and general circumstances are incorporated into the construction of a decision tree. The advantages and disadvantages are evaluated as described in the last chapter.

After all values, submitted by the staff in their estimates, have been averaged and added to determine which alternative is best (highest score) and the decision tree analysis is completed, the PM has adequate information to make a decision. The results of these two methods of analysis and evaluation should yield the same solution as to the best course

of action. If not, recheck all information and calculations to see if a mistake occurred in the tree diagram or in averaging and addition of values. If no mistake is found, then the results of the tree diagram, since it is the most likely and probably the best outcome, should be selected.

The last paragraph contains the decision or recommendation in the case of staff estimates.

If used properly the estimate of circumstances provides a means for provoking an orderly, logical, thorough and comprehensive thought process which is needed to resolve the many complex problems faced by a PM.

PROGRAM MANAGEMENT DECISIONS

Program Managers are charged with developing and producing a product with cost, schedule and technical performance constraints. Consequently, decisions made by a PM must take into consideration these three factors to insure that constraints are not exceeded. So far, specific problems generally faced by a PM have not been discussed. In this chapter it is shown how all of the methods and procedures previously discussed can be related some of the critical problems that occur during the life cycle of a major weapons system. Estimation of cost, schedules and technical performance criteria will be discussed separately and it is shown how these estimates are used in the proposed Estimate of the Circumstances. Finally, the three most critical decisions, should development proceed to validation, full scale development (FSD) or production, will be examined and related to the methods and procedures advocated in this report.

In today's environment cost has become a dominant factor. Congress is continually increasing pressure upon DOD and the services to reduce cost and cost overruns for acquisition of major systems. Recent studies by the GAO indicate that the services have habitually made poor decisions throughout life cycle development. The results of these poor decisions have in some cases increased cost by 200%. (7) Therefore, if the PM and his project is to survive cost must be controlled.

To control cost a PM must first of all establish realistic estimates for the total program to include cost of each development phase. Once these thresholds are established the PMIS and the C/SCSC procedures provide adequate means for monitoring the flow of funds. Unfortunately, neither of the systems can prevent cost overruns or cost increases due to unexpected problems that occur. Therefore, a management reserve is necessary to cover these increases. The task is then to estimate a program cost which includes an adequate reserve.

The current procedures for estimating program cost through the use of parametric, independent, independent government and the PM's cost estimates appear to be adequate. However, to establish the estimate to be used in the development concept paper (DCP) it is proposed that these estimates be averaged to determine the sample mean which would represent the expected cost, but the uncertainties could cause the cost to vary. Therefore, the sample variance should be computed to determine how much the cost could vary and it is proposed that two standard deviations be added to the expected cost. Recognizing that these calculations are approximate and are subject to errors, the percentage of errors can be computed. If the error is 5 or 10% then this percentage of the expected value should be added to the sum of the expected value and the two standard deviations. This value then becomes the estimated cost. This procedure does not guarantee that the cost is exact but it does enhance the possibility that the cost would not exceed this value particularly

since 95% of the values will be below the mean plus two standard deviations with most of the values centered around the mean. (5) Since the values are expected to be centered at the mean and with the two standard deviations plus the correction factor added for errors an adequate management reserve should be available for uncertainties.

This procedure of estimating total program cost should be used whenever an estimate is needed. It is applicable for estimating cost for any situation such as what should an ECP cost.

Comparing this procedure to design of communication systems previously mentioned reveals that it is exactly the same. Expected values plus known deviations are incorporated in establishing decision thresholds used in computer circuitry which are extremely accurate.

Schedules (time) for completion of an activity can be estimated using standard formulas. (2) Using these formulas and the WBS, the network system which contains all the activities to be accomplished, is constructed. In addition to estimating time, formulas exist for predicting the probability that a schedule can be met. The same procedures outlined for estimating cost should be used to establish time schedules for completion of an activity or the entire program and, as mentioned previously in reference to establishing a management reserve for cost, this method should also create a management reserve of time.

Initial technical performance parameters are not established by the PM; therefore, he is not required to estimate or

predict these values. But he is required, based on these parameters, to determine the extent of testing required to validate achievement of the desired degree of performance. The standard formulas, referenced previously, can be used to provide considerable insight as to how many test items (prototypes) and actual tests need be conducted to validate performance. Results of tests can be analyzed, using these same procedures, to determine if desired performance was achieved or, in the case of a fly-off, which prototype performed best.

In some cases an analysis of the factors just described would provide adequate information for making a decision. However, for complex problems the Estimate of Circumstances approach should be used for integration and evaluation of all factors.

Integration of the cost, schedule and technical performance estimates should occur in paragraph 4. An explanation of how estimates were derived, whether they are advantages or disadvantages and their relative importance should be included. Although these factors (cost, etc.) are very important they should be thoroughly analyzed and in light of the particular problem to be resolved. In other words, using the zero to ten scale for relative importance, these factors should not automatically receive a score of ten but whatever is appropriate in view of the circumstances.

Perhaps the most critical problems or decisions a PM must make are deciding if the project is ready to proceed to validation, to FSD or production. These decisions are critical

and proceeding from one of these phases to the other could result in tremendous overruns which habitually occur if decisions are premature. (7)

Many factors must be considered before proceeding to one of these phases. However, techniques and procedures outlined thus far are ideal for analyzing and evaluating complex problems. A thorough and in depth Estimate of the Circumstances should be prepared by each staff section and, if properly prepared without undue emotion, a logical and sound decision is likely to occur.

SUMMARY AND CONCLUSIONS

Most major problems encountered by a PM are directly related to cost, schedule, and technical performance and because these factors are interdependent, an optium sound decision is difficult to make. However difficult and complex, decisions must be made and often must be made within a relatively short time period. Therefore, a PM must have a system that provides an orderly and logical evaluation of all factors related to a problem. Such a system increases the possibility of a PM making the best possible decision.

The methods and procedures advocated in this report provide a system that effectively considers and integrates all factors and thereby produces adequate information for a PM to make a decision. First, the PMIS and C/SCSC predicts cost and schedule data related to development of the hardware. Next, the network system provides an overall view (schedule) of all activities associated with the project. With this system interrelationship of activities and subsequent events or changes to schedules can be accessed. It was also shown that analytical techniques used for sampling, estimation and prediction are powerful techniques and should be used wherever possible. Last, the Estimate of the Circumstances was shown to be an effective means for integrating all factors.

These procedures are directly analogous to procedures used to design complex and extremely accurate electronic systems

particularly computers. Therefore, it can be reasonably concluded that since many uncertainties are accurately judged and predicted in these devices, using these techniques, uncertainties faced by a PM can be handled in the same manner. Consequently, the proposed Estimate of the Circumstances along with the analytical methods greatly enhance the ability of a PM to make sound logical decisions during all phases of life cycle development of a major weapons system.

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